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INVESTIGATION OF MORPHOLOGY CHARACTERIZATION AND MECHANICAL PROPERTIES OF NANO-FLUX (MnO) POWDER FOR TIG WELDING

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ABSTRACT

A lot of experiments have been carried out on varying welding parameters and its effects are studied. Not much work has been done on fluxes for TIG welding. This research work makes use of nano-flux (MnO) welding powder developed from agro waste (banana peel). TIG welding originally do not use flux powder, but in a bid to improve weld properties, flux was introduced. Mild, Galvanized and Stainless steel of plates and Rods were used as parent metals for the experiment. Eight (8) pieces each of Mild and Galvanized steel plates of 50 x 50 x 5mm, Mild and Stainless steel rods of 3.8 x 28mm length were prepared. The samples used were welded in three categories; iincludes without flux, with control (Imported) and nano-flux powder. These samples were subjected to hardness, impact, tensile, SEM and TEM examinations. Results of the hardness in the base metal, weld joint and heat affected zone for the galvanized and mild steel with nano-flux powder gave the best hardness of 206.21, 151.67, 110.56 and 111.95, 120.3, 182.99 BHN respectively. It was also observed that nano-flux welded samples gave maximum impact for mild and stainless steel as 2024.11 and 925.32, tensile stress of mild and stainless steel as 178.47 and 81.59 and tensile strain of mild and stainless steel as 0.0282 and 0.013. Micro-structural analysis results, with the use of SEM and TEM have revealed the micro-structural properties of the weld with the application of the nano-flux to have improved the structure, surface and pattern of the welds as compared to the imported flux and control weld. It also established that application of flux powder in TIG welding improved the welded joint hardness and the structure of the weld.

KEYWORDS: Nano-Flux, Powder, Welding, TIG, Morphology & Characterization

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Original Article

INTRODUCTION

TIG welding is used more widely than other welding processes because of its benefits over them. For the best outcome of this welding process, welding parameters are set to the best environment for the work to be done [1]. The shape of the tungsten electrode used is also considered for best results. The weld speed is chosen based on thickness of base metal and type of inert or active gas used to shield the weld pool. TIG welding involves the use of a tungsten electrode that is non consumable to join two metals together [2]. This tungsten electrode is connected to a power source and there is a release of shielding gas for protection of the weld pool. The shielding gas used may be Helium or Argon. It is used to join metals that are usually difficult to weld. The shielding gas, apart from protecting the weld pool, begins and keeps a stable arc caused by ionization potential that is low [3].

Tungsten dormant gas welding or in other word known as Gas tungsten curve welding is one of the welding procedures among the other welding system. This sort of welding is very used to join the ferrous and non-

ferrous metal [4]. The fundamental thought process of this paper is to deliberate about the ideal parameters for TIG welding. The material properties like tensile quality, hardness of weld joints, generally are influenced by welding parameters. Hence in a decade ago, analysts have worked to locate the ideal parameters for TIG welding [5]. So, this paper surveys the distinctive logical research in TIG welding to locate the best parameter with help of Taguchi procedure. The present paper gives an investigation of improvement on the parameters on TIG welding. From the writing, it is found that there are parcel of work that have improved the situation parameters like current, voltage, gas stream and speed to discover the elasticity, hardness and HAZ [6]. Distinctive parameters (diverse gas, electrode widths, and distinctive structures of filler bars) of process can be taken for welding 309 treated steel with Taguchi and ANOVA technique; [7]; To discover the lingering weight on various parameters amid the welding procedure; To discover the best appropriate parameters for most extreme rigidity, weariness quality, hardness and warmth affected zone [8]. Advances in innovations are important for each industry to get by in rivalry, the welding parameters affect the outcome of this welding process if the parameters are controlled and executed properly would yield a successful outcome [9]. These parameters are affected by the welding environment in which, the process is carried out. TIG welding primarily does not use flux, but a variation was discovered in which, flux powder can be applied on the base metal before it is welded [10]. In some researches done using this variation of TIG welding, it increased the weld penetration by 200%. Welding parameters also known as the factors that affect welding, include welding voltage, welding speed, wire feed rate, shielding gas, flux, welding current, etc., These are variables in which the outcome of the weld is dependent on [11]. In TIG welding, there are major welding parameters that either enhance the weld or deplete it when varied. Feed rate of the wire is measured and regulated in IPM (Inch per Minute). A system in TIG welding feeds the filler wire onto the weld joint. Shape of the weld zone and height is determined by the welding voltage. Electrical current that forms an arc to weld the metal is produced by a power supply. The welding speed is a measure of how fast a work piece moves under the electrode. Shielding gas protects the weld pool form contaminants and oxidation [12].

Desire for knowledge has brought about different numerous ideas and trials of experiments physically by man. Atoms, being the smallest known body to man had not been realized in physical form and the study on this led to the development of nano crystalline materials [13]. Nanoparticles growth mechanism determines distribution function of nanoparticles on size, physical-chemical properties of nano particles medium and etc. They have been investigated a lot with a purpose to understand its varied application needs. They can be prepared in many various processes [14]. The size of the particle is dependent of the process used in preparing it. Nanotechnology is being applied in various areas to cause changes in those areas. Craftsperson often uses nanoparticles to make pots that look as a shiny surface. Nanoparticle qualities were proved by Faraday's "Experimental relations of gold and other metals to light", a paper written in 1857 [15-16]. The properties of nanoparticles make it very relevant, especially in the recent past in the areas like health, agriculture, etc. Not much study has been carried out on nanoparticles concerning what really affects the synthesis process and what hinders the development. Nanoparticles are often needed in large quantity in industries due to the numerous applications [17]. Nanoparticles are complex in nature. The major factors to be considered are light absorption and solubility. The properties include surface, core and shell. Other inherent properties include particle mobility, surface energy and colloid stabilization, Ocular properties and catalysis [18]. Steel has its variety of applications in various industries; a major fabrication process used in manufacture of steel is TIG Welding. These processes are however limited by low weld penetration and weld bead shape of the weld joint [19]. This research is aimed at increasing weld penetration and increase the quality of weld bead shape in TIG welding through the use of flux powder made from nano organic materials and to

enhance the overall general quality of welding joints.

METHODOLOGY

Preparation of the Metals

Eight (8) pieces, each of mild and galvanized steel plates of 50 x 50 x 5mm, mild and stainless steel rods of 3.8 x 28mm length were used. Developed nano-flux welding powder from agro waste (Banana peel) and imported flux welding powder were introduced using TIG welding. The samples used were welded under three categories; iincludes without flux, with control and nano-flux welding powder.

Application of Flux Powder

The faces to be welded were grinded to make it smooth for the best results. The setup was TIG welding. The equipment used in welding is shown below in figure 1. The joint chosen was butt joint, as it is very commonly used. The joints were for similar metals, as shown in figure 2, MS-MS rod. The samples were categorized into three, control (without flux powder), control with imported flux and banana peel flux powder respectively. The TIG welding parameters used are shown in table 1.

Table 1: Welding Parameters for the Experiment

Metals	Current (A)	Voltage (V)	Arc Gap	Gas Flow Rate
Stainless Steel	36	51	5	8
Galvanized Steel	32	51	5	8
Mild Steel	36	51	5	8
Stainless Rod	31	36	4	7
Mild Rod	30	36	4	7

Figure 1: TIG Welding Equipment.

Figure 2: Mild Steel Weld Joint.

Figure 3: Galvanized Steel Weld Joint.

Figure 4: Mild Steel Rod.

RESULTS AND DISCUSSIONS

Hardness Test

Table 2: Hardness test for TIG – Specimen A (Galvanized Steel)

Samples	Base Metal (BHN)	Welded Joint (BHN)	Heat Affected Zone (BHN)
Nano-flux powder	206.21	151.67	110.56
Flux imported	150.44	146.83	90.89
Control (without flux)	143.36	108.85	78.24

For galvanized steel in table 2, the results above showed the hardness between the three zones, which are, base metal, weld joint and heat affected zone when TIG welding was used for Specimen A (Galvanized steel). The hardness in the base metal, when nano-flux powder was used is 206.21 BHN, when imported flux was used, it was 150.44 BHN and when no flux was used, it was 143.36 BHN. It shows that the nano-flux powder has higher hardness than when imported flux was used. The hardness in the welded joint when nano- flux powder was used is 151.67 BHN, when imported flux was used, hardness is 146.83 BHN and when no flux was used, and it showed to be 108.85 BHN. The hardness in the Heat affected zone when nano- flux powder was used is 110.56 BHN, when imported flux was used it was 90.89 BHN and when no flux was used hardness was 78.24 BHN. It can be deduced that the hardness in the heat affected zone when the nano-flux was used is higher than others. The nano- flux powder gave highest hardness among the three zones of the samples.

Table 3: Hardness Test for TIG – Specimen B (Mild Steel)

Samples	Base Metal (BHN)	Welded Joint (BHN)	Heat Affected Zone (BHN)
Developed flux	111.95	120.3	182.99
Flux imported	92.62	111.16	131.59
Control	90.85	85.28	85.81

The results in table 3 show the hardness between of the three zones; base metal, weld joint and heat affected zone when TIG welding was used for Specimen B. The hardness in the base metal, when nano- flux powder was used is 111.95 BHN, when imported flux was used, it was 92.62 BHN and when no flux was used, it was 90.85 BHN. The hardness in the welded joint when nano-flux powder was used is 120.3 BHN, when imported flux was used, hardness is 111.16 BHN and when no flux was used, and it showed to be 85.28 BHN. The hardness in the heat affected zone when nano-flux powder was used is 182.99 BHN, when imported flux was used it was 131.59 BHN and when no flux was used hardness was 85.28 BHN. The nano-flux sample shows more favorable results than the other samples.

Tensile Test

The results showed how the welded joints were affected by the variables they were subject to. Specimen 1 (Mild steel) is a weld joint between two rods, while specimen 2 (Stainless steel) is a weld joint between two rods.

Stress and Strain Graphs

Below are the stress and strain graphs for the various weld specimens

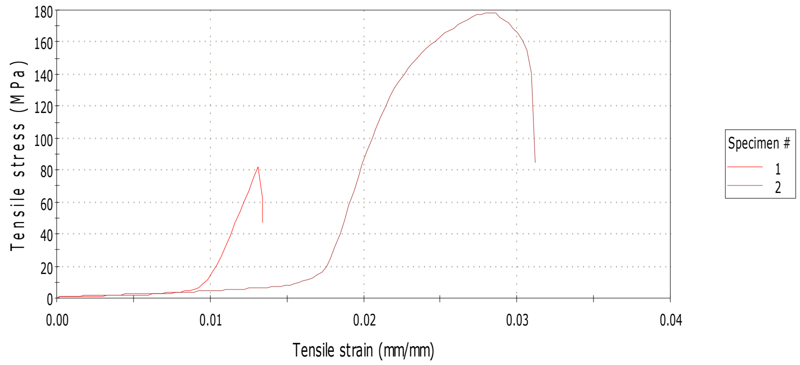

Figure 5: Strain and Strain Curve of TIG Welding with Specimen 1 and 2 with Developed Flux.

Figure 5 shows the behavior of joint between 2 mild steel rods (specimen 1) and 2 stainless steel rods (specimen 2). Specimen 1 possesses relatively low yield strength when compared to Specimen 2. Specimen 1 is brittle due to the little plastic deformation it experiences before it fractures and Specimen 2 is more ductile because it experiences a larger plastic deformation. When compared on the basis of yield strength, Specimen 2 is more brittle than Specimen 1 because of its higher yield strength. Where Specimen 1 experiences a relatively small phase of necking, Specimen 2 starts experiencing necking right after its ultimate strength has been reached. At the phase of necking, it experiences fracture at a low tensile stress. Figure 5 also shows the behavior of joint between 2 Mild steel rods (Specimen 2) and 2 stainless steel rods (Specimen 1). Specimen 1 has a high yield strength and little plastic deformation before it necks and then fractures. The quality of high yield strength and little plastic deformation shows that the joint is brittle. Specimen 2 has high yield strength also, but it undergoes a large phase of plastic deformation before it reaches ultimate strength and then necking begins. This phase of plastic deformation shows that specimen 2 is more ductile than brittle in comparison to Specimen 1.

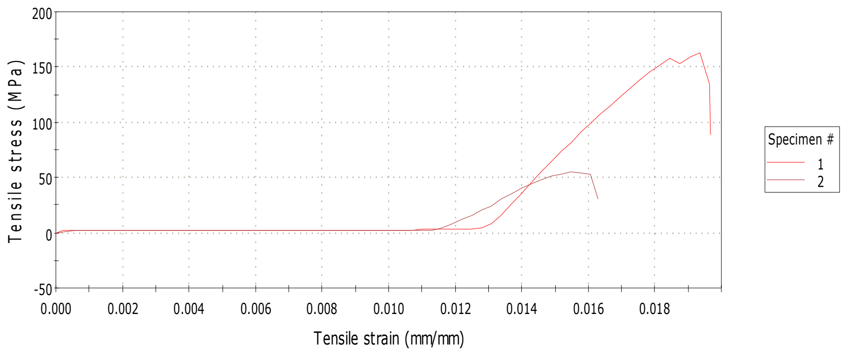

Figure 6: Strain and Strain Curve of TIG Welding with Specimen 1 and 2 with Imported Flux.

The behavior of joint between 2 Mild steel rods (Specimen 1) and 2 Stainless steel rods (Specimen 2) is shown in figure 6 above. Specimen 1 behaves in a brittle manner as it possesses high yield strength with little plastic deformation before it reaches ultimate strength and then necks before fracturing. Specimen 2, with its relatively low yield strength shows to be more ductile, but it also possesses a small phase of plastic deformation. The two specimens undergo plastic deformation at a constant tensile stress until a particular tensile stain is reached. The necking of specimen 1 occurs in more tensile stress than that of Specimen 2.

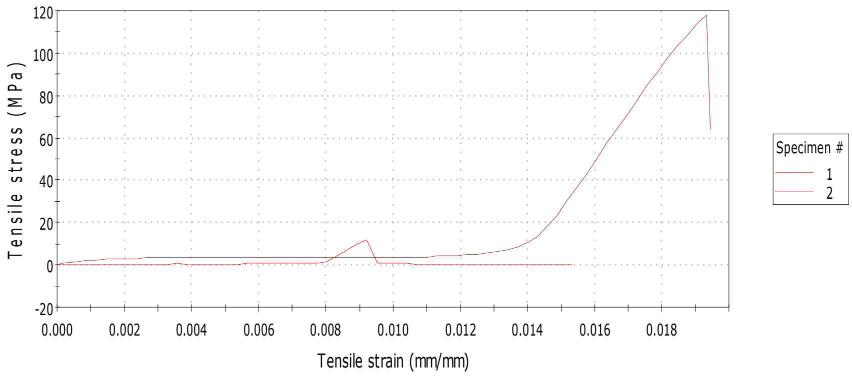

Figure 7: Strain and Strain Curve of TIG Welding with Specimen 1 and 2 without Flux.

The behavior of joint between 2 Mild steel rods (Specimen 1) and 2 Stainless steel rods (Specimen 2) is shown in figure 7 above. Specimen 1 goes through an irregular phase in the graph. The point at which the yield strength shows to be of increase where the plastic deformation starts and it necks at a constant tensile stress while experiencing tensile strain before fracturing. Specimen 2 has high yield strength and also plastic deformation is very little before it starts necking which means that the joint is brittle. It can be said that specimen 1 is brittle only because of its low yield strength in comparison with specimen 2.

Impact Test

Table 4: Maximum Load for Specimen 1 (Mild Steel)

Samples	TIG
Nano-Flux	2024.11078
Flux imported	1844.57563
Control	1334.90730

Table 4 above shows the TIG welding, when developed flux powder was used, the maximum load is 2024.11078N. When imported flux was used, the maximum load it was able to withstand is 1844.57563N. When no flux was used, the maximum load it was able to withstand is 1334.90730N. It can be deduced that the maximum load in specimen 1 (Mild steel) was highest for developed flux powder in TIG welding than for the imported flux sample and the control sample.

Table 5: Maximum Load for Specimen 2 (Stainless Steel)

Samples	TIG
Nano-flux powder	925.31955
Flux imported	625.97743
Control	133.74157

As is shown in the table 5, In TIG welding, when developed flux powder was used, the maximum load is 925.31955N. When imported flux was used, the maximum load it was able to withstand is 625.97743N. When no flux was used, the maximum load it was able to withstand is 133.74157N. It is seen that the joint made with banana flux powder withstood the highest load, followed by the joint made with the imported flux powder. It can be deduced that the maximum load in Specimen 2 (Stainless steel) was highest for nano-flux powder in TIG welding than for the imported flux sample and the control sample.

Table 6: Maximum Tensile Stress for Specimen 1 (Mild Steel)

Samples	TIG
Developed flux	178.47493
Flux imported	162.64451
Control	117.70476

It is shown from the table 6 and figure 7 above that, when nano-flux powder was used, the maximum tensile stress is 178.47493MPa. When imported flux was used, the maximum tensile stress is 162.64451MPa. When no flux was used, the maximum tensile stress is 117.70476MPa. It is seen that the joint made using the developed flux powder in TIG welding has the highest maximum tensile stress. The maximum tensile stress of the joint made using the imported flux powder is greater than that of when no flux was used. The results for Specimen 1 (Mild steel) in the maximum tensile stress are similar to that of the maximum load results. The developed flux powder gave better results when used for TIG welding as shown in the graph above. It can be said that when using the nano- flux powder, it is more efficient in TIG welding.

Table 7: Maximum Tensile Stress for Specimen 2 (Stainless Steel)

Samples	TIG
Developed flux	81.58957
Flux imported	55.19524
Control	11.79259

It is shown from the table 7, In TIG welding, when nano-flux powder was used, the maximum tensile stress is 81.58957MPa. When imported flux was used, the maximum tensile stress is 55.19524MPa. When no flux was used, the maximum tensile stress is 11.79259MPa. It is seen that the joint made using the nano-flux powder in TIG welding has the highest maximum tensile stress. The maximum tensile stress of the joint made using the imported flux powder is greater than that of when no flux was used during TIG welding. In tensile stress for Specimen 2 (Stainless steel), the sample with developed flux powder has a higher tensile stress in TIG welding than the sample with imported flux and the control sample.

Table 8: Maximum Tensile Strain for Specimen 1 (Mild Steel)

Samples	TIG
Developed flux	0.02828
Flux imported	0.01935
control	0.01934

In table 8, in TIG welding when nano-flux powder was used, the maximum tensile strain is 0.02828. When imported flux was used, the maximum tensile strain is 0.01935. When no flux was used, the maximum tensile strain is 0.01934. Elongation on the sample was most when the nano-flux powder was used followed by imported flux powder, and then the sample without flux elongated the least. The results for Specimen 1 (Mild steel) in the maximum tensile strain are similar to that of the maximum load results. The developed flux powder gave the highest maximum tensile strain amongst other samples when used for TIG welding.

Table 9: Maximum Tensile Strain for Specimen 2 (Stainless Steel)

Samples	TIG
Developed flux	0.01310
Flux imported	0.01548
control	0.00922

In table 9, when nano-flux powder was used, the maximum tensile strain is 0.01310. When imported flux was used, the maximum tensile strain is 0.01548. When no flux was used, the maximum tensile strain is 0.00922. It can be said that the elongation before failure when the developed flux powder was used is more than when no flux was used. Also, the elongation of the sample welded with the developed flux powder is higher in TIG welding. Tensile strain for specimen 2 (stainless steel) is more in TIG welding.

SEM and TEM Test Results

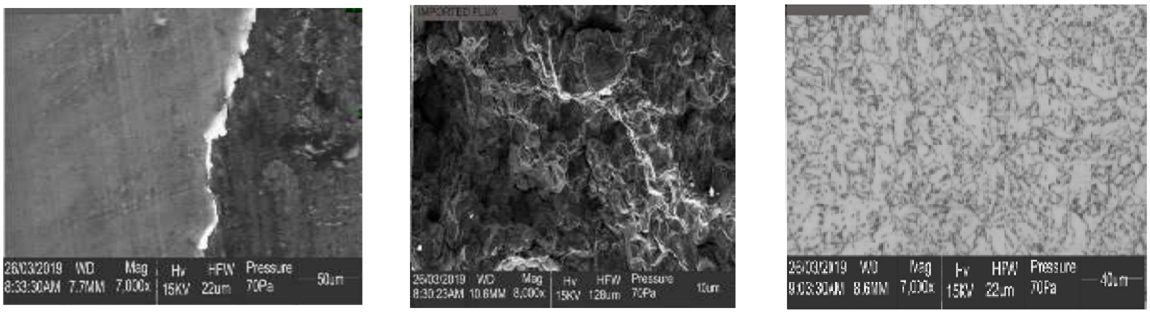

Figure 8: SEM Image of Mild Steel Joint a) without Flux b) with Imported Flux and c) with Nano-flux.

Figure 8 showed micro-structural image in joints of Mild steel samples. It was observed that large size particles interlocked together which may be pearlitic and ferritic structures distributed in the matrix uniformly was found in control sample. The SEM micrograph of Mild steel welded using the nano-flux and the TIG welding process showed no variation with the non-existence of air gaps which shows a smooth weld. Strengthening dislocations were also present in this micro-structure, but they are not as plenty as those in the weld created using the nano-flux. The micro-structure of the TIG weld of the galvanized steel was found to be very disordered in the weld made with imported flux. There was a distinct separation seen between the two metals of the weld done without the use of flux. The imported flux sample has a rough surface with a lot of holes and cavities in the weld, making it weaker than the other two samples. The weld done with nano-flux has the best structural arrangement.

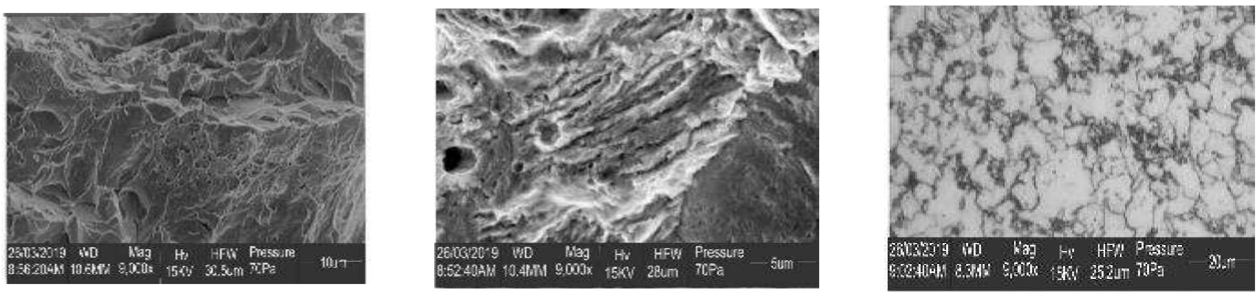

Figure 9: SEM Image of Galvanize Steel Joint a) without Flux b) with Imported Flux and c) with Developed Flux.

Figure 9 shows SEM image for the Galvanize steel samples. From the SEM image, the micro-structure of the control is different from that of the fluxed samples. It can be observed that the grain structure primarily consists of grains with non-epitaxial growth like bridges, which may be ferritic structure lazed with minimal pearlites, there are some air holes in the SEM image for imported flux sample and it is dominated with more ferritic structure which is the influence of the flux used. Similarly, the structure of the nano-flux sample reflects high presence of Mn_3C particles dispersed in the Fe matrix. While the weld made without flux is seen to have a rough surface without and holes, that of the imported flux has holes present with contours and needle like lines. The weld made with the nano-flux have a relatively smooth surface when compared to the weld without flux and the weld with imported flux.

CONCLUSIONS

From the results and discussion, TIG welding was carried out under the application of nano-flux and imported flux welding powder and its effects on the weld was studied as applied to TIG welding. Below is a summary of the results:

- The mechanical properties of the characterization of the produced welds has proven that the nano-flux to have better effects in TIG welding of Galvanized and Mild steel and these effects were more in the TIG welding when the nano-flux was used.
- When the nano-flux was used, Mild steel joints showed to be more brittle than ductile in TIG welding and also stainless steel joints showed to be more ductile than brittle. This is because of the short phase of plastic deformation for Mild steel joint samples in comparison with the Stainless steel joints samples.
- Hardness of the welded joints for the three zones of the Mild and Galvanise steel were carried out using Vickers hardness tester. The welded joints produced using the nano-flux powder was found to have highest hardness values of 206.21, 151.67, 110.56 and111.95, 120.3, 182.99 BHN respectively compared with the imported flux and weld without flux samples.
- The Micro-structural analysis results with the use of Scanning Electron Microscope have revealed that the micro-structural properties of the weld with the application of the nano-flux to have improved the structure, surface and pattern of the welds as compared to the imported flux and control weld.

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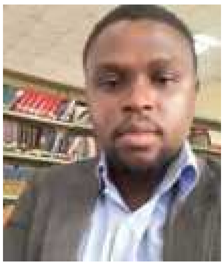

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